$^{40}Ar/^{39}Ar$ thermochronology of unbrecciated eucrites & diogenites: clues to the crustal formation of Vesta.

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Eucrites are extraterrestrial basalts and cumulate gabbros formed, and subsequently more or less metamorphosed, at the crustal level of the HED (Howardite-Eucrite-Diogenite) parent body, thought to be the asteroid 4-Vesta. Unbrecciated eucrites (Mayne et al., 2009) offer the best way to understand the igneous, metamorphic and cooling processes occurring in the crust of Vesta since they were not substantially affected/altered by secondary impact processes. The $^{40}Ar/^{39}Ar$ system of unbrecciated eucrites should be in a relatively pristine state, and thus can inform us on the early volcanic and thermal history of the HED parent body, and, in particular, the cooling history of various crustal parts below the 300-250 °C isotherm, which represent the closure temperature of the Ar diffusion in plagioclase (Cassata and Renne, 2013). Diogenites are orthopyroxenites wich sometimes contain minor amount of olivine and plagioclase (Yamaguchi et al., 2011).

We analyzed plagioclase and pyroxene (± groundmass) separates of 2 cumulate (Moore County and Moama), and 6 basaltic eucrites and 1 olivine diogenite (LAP 031381) with the $^{40}Ar/^{39}Ar$ technique using a Thermo© ARGUS VI multi-collection mass spectrometer. The textures of the basaltic samples range from gabbroic (Caldera) and granoblastic (BTN00300, EET90020, GRA98098, QUE97053) to unequilibrated fine-grained (PCA82502). The fine-grained sample yielded an age of 4531 ± 6 Ma which we interpret as the age of a shallow impact melt rock and is the first direct evidence that most, if not all, of the uppermost crust was already formed/erupted by 4531 Ma. The two cumulate eucrites yielded ages 4531 ± 11 Ma and 4533 ± 12 Ma and when coupled with estimated cooling rates, suggest that magma chambers were still active in the upper crust of Vesta at ca. 4530-4535 Ma. The granulite ages when coupled with a sixth sample (Lake Carnegie) with $^{40}Ar/^{39}Ar$ ages published by (Kennedy et al., 2013), show a well-defined cluster of ages between 4507 ± 20 Ma to 4523 ± 8 Ma for five samples, whereas an impact age of 4531 ± 5 Ma was obtained for EET90020. Those ages indicate when the mid-lower crust, where those granulites probably resided, cooled below 300°C and suggest a cooling rate of 17 ± 4 °C / Ma (2σ) for the mid- to lower-crust of Vesta since the time of the peak metamorphism at ca. 4555 Ma (Iizuka et al., 2015). This is in agreement with the cooling numerical model proposed by (Zhou et al., 2013). Such a cooling rate is to be compared with the cooling rate of ~ 10 °C/Ma derived from the multi-mineral thermochronological analyses of Agoult indicating the latter eucrite resided deeper in the crust, probably at the bottom lower crust (Iizuka et al., this meeting).

We analysed pyroxene separates from 19 diogenites but a large majority of the data were affected by secondary impacts and yielded severely perturbed age spectra. Only LAP031381 yielded two plateau ages of 4420 ± 22 Ma (#5A, fine fraction) and 4501 ± 14 Ma (5B, coarse fraction). The pyroxene age of 4501 ± 14 is similar to the plagioclase $^{40}Ar/^{39}Ar$ age of equilibrated eucrites (4523 ± 8 Ma to 4493 ± 9 Ma; This study & Iizuka et al., this meeting), *however,* the closure temperature of orthopyroxene is ca. 620°C, significantly higher than plagioclase. This means that LAP031381 cooled down at a cooling rate of 6-7 °C/Ma, much more slowly than the equilibrated eucrites (17 ± 4 °C) and even more slowly than Agoult (~10°C/Ma). This suggest that LAP031381 was located in the lowermost crust, perhaps at the crust/mantle interface.

References

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